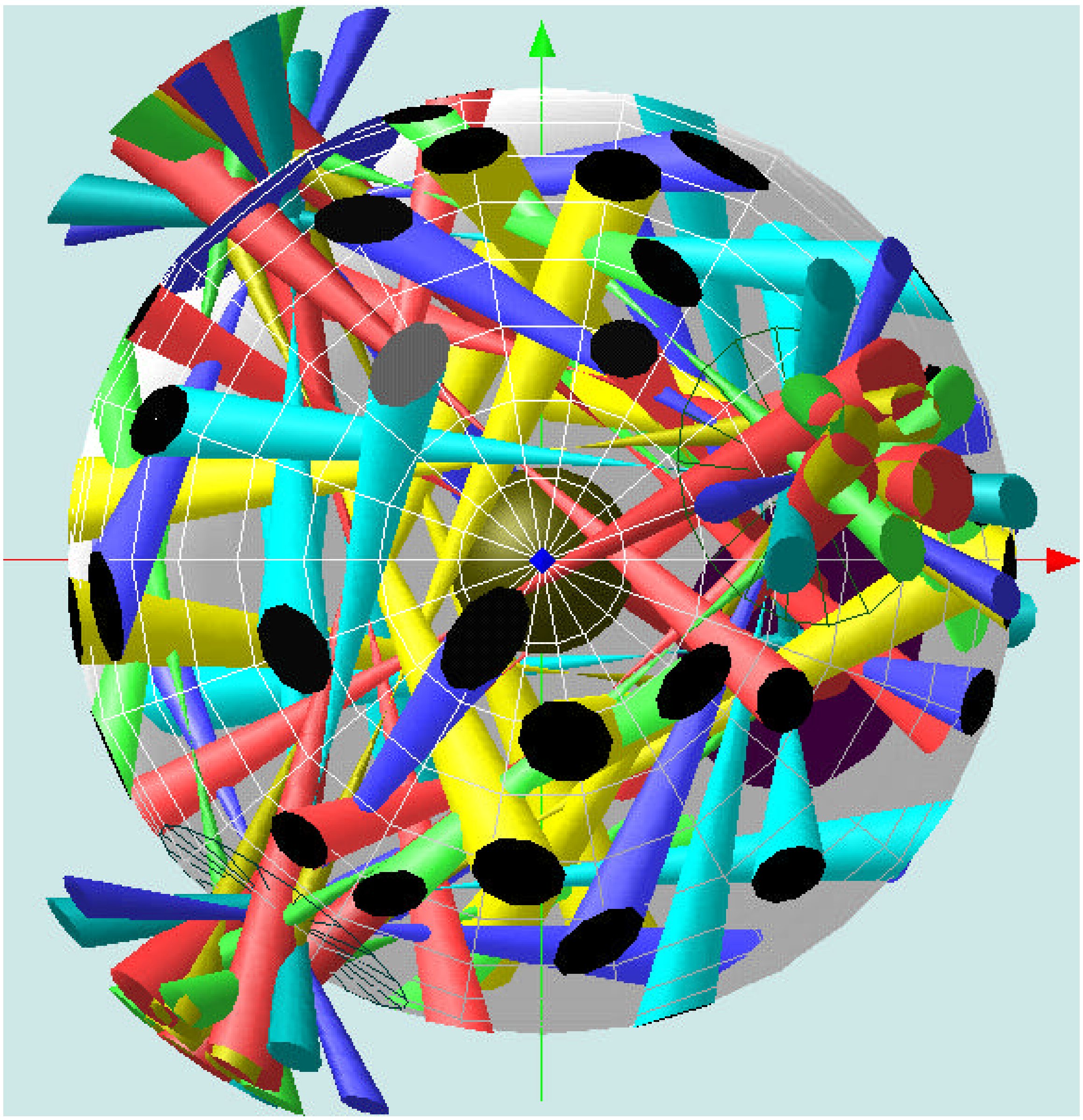
LA-UR 99-1100

Los Alamos Inertial Confinement Fusion

FY97 Accomplishments

December 16, 1997



Omega Spherical Hohlraum with Tetrahedral Illumination
60 Omega beams enter a 1.4 mm radius sphere through four laser entrance holes.

I. Introduction

The Los Alamos Inertial Confinement Fusion (ICF) Program has two principal goals: 1) to perform research that is central to the achievement of ignition on the National Ignition Facility (NIF), and 2) to develop and utilize ICF techniques and methods in pursuit of core nuclear weapons research. These goals have driven a program that includes experiments on various high energy laser facilities, advanced theoretical modeling, and target fabrication materials research.

In FY97, the Los Alamos ICF program began shifting research emphasis from ignition research to nuclear weapons physics research using lasers. This has resulted in a closer coupling between the core weapons program at Los Alamos and the ICF program. The transition has been smooth as the capabilities and expertise required for implementing the new ICF weapons physics-based program largely overlaps that of the old ignition-based program. Additionally, there is considerable overlap between weapons physics and ignition research. Many of the experimental campaigns we have conducted are relevant to both ignition and weapons physics.

Within our ICF program, we have briefly outlined our principal accomplishments addressing critical ignition issues and weapons physics within DOE's Stewardship Program. Many of these campaigns have involved collaborations with Lawrence Livermore National Laboratory, University of Rochester/Laboratory for Laser Energetics, General Atomics, and to a limited extent Sandia National Laboratory and the Naval Research Laboratory. We outline our principal accomplishments from FY97 in this report.

II. Hohlraum Physics

Understanding hohlraum plasma dynamics is critical to attaining ignition as well as for effectively utilizing indirect drive for weapons physics experiments. Laser-heated hohlraums are the mainline approach for driving high performance implosions and for heating and accelerating packages used in weapons physics experiments. In indirect drive, the laser couples its energy into a cavity (hohlraum) made of a material with high atomic number. Such materials efficiently convert laser energy to x-rays and create a radiation environment which can be tailored to drive implosions or radioactively heat non-imploding targets. Plasma evolution within a hohlraum is very complex involving many physical processes. In order to optimize indirect drive for ignition and weapons physics, we must have a thorough understanding of radiation illumination symmetry and laser plasma instabilities.

Significant progress has been made in developing methods for measuring and controlling the symmetry of the hohlraum radiation field that heats and implodes capsules. To achieve ignition on NIF, it is essential to limit radiation asymmetries on the capsule to less than 2% time-averaged over the duration of the drive. In addition, time-dependent fluctuations in symmetry (over a few nanoseconds) must be controlled to better than 10% rms. Control of these symmetry fluctuations will be accomplished on NIF through beam phasing (independent laser beam power control) of the inner and outer cones of illumination.

Laser-plasma instabilities can scatter laser light into undesirable directions including backwards out of the hohlraum. This can be deleterious to hohlraum energetics as well as a source of capsule implosion asymmetry. In order to achieve ignition, laser plasma instabilities must be controlled. To date, we employ a phenomenological and often qualitative understanding of self-focusing, stimulated Raman scattering (SRS), and stimulated Brillioun scattering (SBS). We can not quantitatively predict laser plasma instability levels for nominal plasma conditions on NIF nor can we confidently conclude that 500 eV radiation temperature hohlraums will be a viable tool on NIF for weapons physics. Greater understanding of the processes controlling the nonlinear saturation levels of SBS, SRS, filamentation and two-plasmon decay (TPD) is the main challenge.

In FY97, Los Alamos has concluded in depth studies of symmetry on Nova, continued studies of laser plasma instability, and has begun to develop advanced hohlraums. The symmetry experiments have focused on understanding whether good hohlraum symmetry could be achieved in gas-filled hohlraums if laser beam smoothing was used. Previous experiments showed that laser beams bend in gas-filled hohlraums in an unpredictable way. To assure that good symmetry can be obtained on NIF, experiments continued to investigate the means to control the beam bending effect. Additionally, we began a campaign in specialized hohlraums to better understand radiation flow. These experiments are called the English Concept experiments.

Accomplishments:

Symmetry

- Symmetry experiments using 10 Kineform Phase Plate (KPP)-smoothed laser beams have been carried out and have shown beam smoothing reduces beam bending in gas-filled hohlraums.

Background: Time integrated symmetry experiments in gas-filled hohlraums show a 150 micron shift in laser pointing is required to obtain a symmetric capsule implosion as compared to laser pointing for round images in vacuum hohlraums. This beam bending was hypothesized to be due to the plasma motion inside the hohlraum moving hot spots in the laser beams. By using KPP's to smooth the laser beams and hence remove the hot spots, beam bending was significantly reduced.

Advanced Hohlraum Development

- Spherical hohlraums with a tetrahedral arrangement of laser entrance holes demonstrated the highest radiation temperatures achieved on Omega in indirect drive experiments (about 230 eV). These experiments made use of all of Omega's 60 beams to drive these hohlraums.

- Spherical hohlraums were used to study drive symmetry on Omega. Two sets of experiments were completed varying laser entrance hole size to control drive symmetry. Very symmetric implosions were produced with yields comparing well with clean 1-D calculations. The time integrated symmetry is estimated to be 2-3%, similar to the symmetry required on NIF.

- The first successful English Concept experiments were performed on the Nova laser. [G. R. Magelssen *et al.*, NEDPC (1997)]

Laser Plasma Instabilities Experiments

SRS and SBS was spatially imaged in toroidal NIF-like plasma conditions using the FABSI backscatter diagnostic. The FABS diagnostic has 50 μm spatial resolution and four frames per shot. This is the first time that SRS and SBS backscatter have been simultaneously imaged in a hohlraum on Nova.

Laser Plasma Instability Theory

- ASPEN, a two-dimensional, fully kinetic particle-in-cell model was developed and implemented on the massively parallel CRAY-T3D. This is the most ambitious and sophisticated attempt to date to simulate SBS and SRS processes occurring in laser-produced plasmas. Quantitative comparisons between ASPEN and the well known reduced Zakharov model have begun to both benchmark the ASPEN calculations and to understand the limitations of the Zakharov approach.

- The effects of nonlinear ion kinetic effects in stimulated Brillouin scattering in laser-produced plasmas have been studied. It has been found that when the laser is sufficiently strong, ion trapping determines the saturation level and the nonlinear frequency shift of the waves.

- A LASNEX postprocessor that models the effects of both SRS and SBS parametric processes in hohlraums has been developed. This postprocessor is now being used to study hohlraum conditions that are likely to produce SRS and SBS. Results to date are consistent with experimental data.

- A statistically based scheme to solve the paraxial wave equation has been developed and used to obtain analytic solutions for the beam bending rate in the presence of plasma flow. This scheme predicts beam bending consistent with the FY96 experimental data. The plasma flow induced by SBS and SRS is spatially inhomogeneous and this causes a spatially varying Doppler shift of the SBS daughter acoustic wave frequency, limiting the spatial region over which SBS can be amplified. This is one mechanism which causes SBS to be self limiting, and causes SRS to interfere destructively with SBS. If the background plasma is quasi-homogeneous, as in some present experiments and presumably in a NIF hohlraum, this may be an important control mechanism for SBS.

- Self-generated plasma flow, by both the stimulated Brillouin and Raman scattering processes (SBS and SRS) was shown to dramatically inhibit SBS.

- Closed-form analytic expressions for beam deflection in certain parameter regimes have been obtained: when the laser beam is smoothed solely by random phase plate (RPP) optics; when in addition, the beam is temporarily smoothed either by the method of induced spatial incoherence, or when the beam is smoothed by the technique of smoothing by spectral dispersion (SSD).

- It has been found that for a plasma with strong acoustic wave damping and moderate flow Mach number, there can be significant power transfer between crossed, RPP conditioned, laser beams. The amount of bandwidth available with SSD may not be sufficient to adequately suppress this process. This implies that the only way to effectively control this transfer is to have a two color scheme, with the inner NIF cone beams having a different frequency than the outer. If this two color scheme is not implemented there will be significant power transfer between the inner and outer NIF beam cones, making it that much harder to control symmetry.

- New results on the scaling with wave damping parameters, laser power, and plasma density of the SRS reflectivity and of the power dissipated in plasma waves have been obtained. These results compare well with predictions of a new mesoscaling theory of SRS. This modeling may allow simulations of systems of macroscopic size including, ultimately, NIF sizes.

- The effect of various forms of temporal beam smoothing on beam deflection by flow has been analytically evaluated, and shown to decrease beam deflection for NIF relevant plasma. [S. Ghosal, *et al*., *Physics of Plasmas*, December 1997] It was shown that in the limit of a large number of color cycles, *Ncc,* the effect is identical to that of the induced spatial incoherence method of temporal smoothing. For small *Ncc*, the beam deflection rate may be significantly larger in the direction perpendicular to the dispersion, than in the parallel direction. Therefore, the spectral dispersion direction should be chosen radially for each NIF beam to minimize residual deflection.

- Two-dimensional reduced-model simulations of SRS from a single laser hot have been performed. New results on the scaling with wave damping parameters, laser power, and plasma density of the SRS reflectivity and of the power dissipated in plasma waves have been obtained. These results compare well with predictions of a new mesoscaling theory of SRS. Mesoscale modeling of SRS, which is an attempt to derive nonlinear equations for the saturation of SRS in which the small turbulent scales have been integrated out, may allow simulations of systems of macroscopic size including, ultimately, NIF sizes.

III. Capsule Implosion and Hydrodynamic Physics

Accurate computational modeling of the hydrodynamics of imploding capsules is crucial for an ignition demonstration in ICF because of the importance of such phenomena as accurate shock-wave timing, radiation and thermal electron ablation, the development of the central hot core, and the effect of hydrodynamic instability. Furthermore, improved understanding of implosion hydrodynamics is important for the enduring nuclear stockpile and is an area in which ICF can make valuable contributions to predictive capability in core weapons programs.

Hydrodynamics experiments in FY97 have primarily concentrated on understanding the growth of instabilities. Finishing up our study of linear Rayleigh-Taylor (RT) in indirect drive cylindrical geometry, we shifted our focus to understanding:

- feed-out of perturbations at the fuel gas-ice interface and subsequent feed-in of perturbations through the capsule shell;
- non-linear behavior of defects. This is another issue of significant relevance to the weapons program and an example of synergism between ICF and core weapons.
- foam buffering technique which can potentially smooth laser nonuniformities for direct drive. Use of foam layers surrounding targets creates a thermally conducting low density plasma around the solid shell of the capsule, to isolate the laser absorption region from the ablation surface, and permit lateral thermal transport to smooth out laser nonuniformities. Such a technique may be critical to successful direct drive ignition on NIF and may create more efficient direct drive in the heating and acceleration of packages utilized in hydrodynamic weapons physics experiments.

Accomplishments:

- An experiment was designed for Omega to study convergent hydrodynamics in cylindrical geometry. Designed for direct drive illumination, the experiment uses the special capabilities of the Omega facility to drive cylinders with twice the diameter of previous indirect drive experiments. This should provide increased experimental resolution, ability to study higher mode numbers, and increased acceleration distance and more growth. Part of the design work included extensive efforts at improving the capability of LASNEX to simulate direct drive laser interactions. Backlighter tests and initial implosions are scheduled for FY98.

  Background: Imploding-cylinder instability experiments at Omega are the next step in our campaign to validate our theoretical and computational modeling of hydrodynamic instability in convergent geometry. Implosion experiments at modest convergence can be driven more efficiently with direct drive at Omega, thus enabling high velocities and/or larger sample sizes and allowing access to larger regimes of implosion parameter space. We expect that these new experiments can be carried out with larger space and time scales than past experiments, permitting better resolution of structures and the use of higher perturbation modes. In addition, cylindrical experiments may provide an important vehicle for testing some aspects of cryogenic target implosions.

- Experimental data of the feed-out, or the coupling of rear-surface Richtmyer-Meshkov instability with front-surface ablative Rayleigh-Taylor instability in planar foils at Nova was analyzed. This showed that the details of feed-out involve the generation of "acoustic-gravity waves," in which the accelerated foil oscillates much like the earth's atmosphere does, when buoyancy and compressibility are of comparable importance [N.M. Hoffman, BAPS **42**, 1953 (1997)].

  Background: In calculations of NIF capsules, perturbations on the inner surface of the shell propagate outward or “feed-out” to the ablation surface where they are amplified, and later “feed-in” again to the inside of the capsule, interfering with ignition. Thus, the feed-out/feed-in mechanism has an important effect on NIF capsule performance. The details of this process involve the coupling of Richtmyer-Meshkov instability on the inside of the shell with ablative Rayleigh-Taylor instability at the outside of the shell. Because of the importance of hydrodynamic instabilities in NIF implosions, it is necessary to verify our understanding of this process by means of Nova experiments which can approximate the expected phenomenology on NIF.

- The hydrodynamics of single point joint defects mocking up NIF Be ignition capsule joints was studied in planar geometry on Nova, testing our ability to make accurate prediction of joint evolution. The behavior of the joint depends on the relative density of the joint material compared to that of the bulk target material.

  Background: Some NIF ablator materials require fabrication techniques that lead to unavoidable isolated perturbations such as joints, chambers, plugs, and/or fill tubes. A distinguishing feature of such defects is that they are initialized in the nonlinear regime; that is, their initial amplitude is comparable to or even much larger than their wavelength. Thus, the growth of such a perturbation occurs in both wavelength and amplitude, so that defects of rather small initial scale can become quite large. An assessment of the effect of fabrication defects in ablators is critical to using these materials for an ignition demonstration. We exercise our predictive capability for a variety of defects that could harm capsule performance on NIF.

- It has been demonstrated experimentally, in accordance with theoretical predictions, that shock nonuniformities generated by joints can extend perpendicularly out from joints for distances an order of magnitude greater than the joint thickness.

- RAGE calculations have been done to help guide the planned experimental study of defects in cylindrical geometry. The purpose of the study is to understand how the size of defects vary in a convergent geometry.

- LASNEX has established that both the growth rate and absolute level of Rayleigh-Taylor instability is reduced by the presence of a foam buffering layer. Parameter studies have shown that foam mitigation is most effective at higher laser intensities. The microdynamics of structured foams has been studied in various scenarios, in order to determine the homogenization times of the foam layers routinely used to ameliorate early time laser imprint in direct drive ICF applications.

  Background: Foam buffers allow lateral thermal transport to smooth laser-drive nonuniformities, avoiding disruption of an implosion by strong hydrodynamic instability. The foam buffered direct drive program has been examining such buffers, created from a low density plastic foam, at both 527 nm and 351 nm drive wavelength. This program has conducted experiments in planar, cylindrical, and spherical geometry to study both the interaction physics and the engineering aspects of creating the low density foam coated targets. This method, which has predominantly been developed on the Trident laser, may also make possible the use of more efficient direct drive in the heating and acceleration of packages utilized in hydrodynamic weapons physics experiments.

- 1-D calculations with LASNEX have established that a gold preheat layer facing the laser in the foam-buffer package hastens the conversion of structured-foam to a uniform foam-plasma, which aids disturbance mitigation.

- A gold preheat layer facing the laser in the foam buffer package has been studied on Vulcan. It has been established that the gold layer launches a supersonic ionization front, followed by a shock of varying strength, in the foam.

- In 2-D calculations, effective beam smoothing due to foam buffers has been traced to the high electron thermal conductivity of the foam plasma.

- The first "cylindrical gap" experiments were performed in collaboration with researchers from AWE in Aldermaston on the Nova. Using plastic cylinders designed by AWE, we imaged implosions of cylinders with V-shaped notches on outside to study nonlinear defect hydrodynamics. This experiment is now under active comparison to various code simulations; follow-on experiments possibly using copper doped beryllium cylinders are under design.

- We continued studies of ablative Rayleigh-Taylor and convergent Bell-Plesset growth in cylindrical geometry, with emphasis on nonlinear behavior of modes. This included looking at mode coupling between illumination asymmetry and machined perturbations as well as behavior of large initial perturbations that quickly become nonlinear.

Background: NIF capsules are highly unstable during implosion, so it is crucial to verify our understanding of instability processes and our ability to control them. Experiments in convergent geometry are necessary because of numerous unique effects which do not occur in planar geometry. Our cylindrical implosion experiments permit direct imaging of growing perturbations in convergent geometry, allowing stringent assessment of the accuracy of LASNEX simulations.

- In indirect drive cylindrical implosion experiments, we confirmed a prediction of radiographic contrast being dominated by radial densification of implosion rather than opacity of marker material. Targets were fielded without a chlorinated marker layer compared to simulations.

The first demonstration of time resolved multiplane diffraction for measurement of dynamic materials properties was completed on Trident.

IV. Shock Wave Physics and Materials Science

Propagation of moderate strength shocks in condensed matter and plasmas is of considerable importance to ICF and weapons. Some of the important phenomena are:

- behavior of materials in response to moderate strength shocks, i.e. in the regime where strength of materials is still of importance;
- solid phase transitions in response to shock loading;
- behavior of fuel capsule materials during the early ("foot") drive in ignition designs;
- and "imprinting" of perturbations in the early phase of direct drive laser fusion.

We have begun a program to develop measurement methods to address these and related phenomena.

During this past year we have conducted experiments at both the Trident laser at Los Alamos and Nova that address some of these issues. One important project in this area has been the development of transient x-ray diffraction. In a collaborative effort with Oxford University and Lawrence Livermore National Laboratory (LLNL), we have been developing transient x-ray diffraction as a diagnostic method for phenomena such as materials phase changes and direct drive imprint. Shocks (ranging in strength from about 1200 kilobars to many Mbars) are driven into samples of material with a degree of crystal regularity. The shocks can be driven by direct laser ablation or by laser-heated hohlraums. Another beam of the laser system is used to excite a point x-ray source. The x-rays then diffract off of various planes in the crystal. The diffraction occurs according to Bragg's law: $2d\mathrm{Sin}\theta = \lambda$ so that for constant x-ray wavelength compression of the material (change in 2d) by a shock will result in a change in the diffracted angle. We have conducted experiments with the shock launched into the x-ray entrance face of the crystal and tests where the shock is initiated on the opposite face and shock breakout is observed.

One of the important phenomenon that can be studied with this technique is the behavior of plastic waves and the generation of dislocations in materials. A shock wave propagating through condensed matter will produce uniaxial strain along the shock propagation as long as the material is responding elastically. If the shock is beyond the yield point there can be a plastic component to the material response. In order to assess this behavior, it is necessary to diffract off of more than one plane simultaneously (i.e. sensing the strain component an angle to the shock propagation). One milestone this fiscal year was to demonstrate that such a measurement could be performed. Diffraction from two orthogonal sets of planes is time resolved with two x-ray streak cameras. Data represents lineouts through the streaked data and thus are diffracted spectra at a particular time. Large spikes in the data are from x-rays diffracted from unshocked material (used as a reference) and diffraction from shocked material is indicated. 3D compression has definitely been observed in these samples of LiF crystals. Similar experiments on the Nova laser, with silicon where the shock is excited with hohlraum drive, have not yet shown the orthogonal component of strain. At the pressure employed the two materials should respond similarly. We are pursuing the origin of this seeming discrepancy.

Accomplishments:

- Theoretical predictions of laser pulse shapes have been made for near-term direct drive material properties experiments on Trident which require well characterized shock waves to propagate with constant strength through the material samples.

- The simultaneous time resolved multiplane diffraction was demonstrated.

  Background: This technique will be applied to the study of plastic waves in materials, dislocation generation and phase transitions.

- The use of transient diffraction in the study of direct drive imprint was demonstrated.

  Background: Transient diffraction senses perturbations in the low pressure shock in the early phase of direct drive. Diffraction measures changes in compression (strain) rather than mass movement that is utilized by other methods. This provides a more complete characterization of the imprinting process.

- The design and initiation of construction of an ultrahigh resolution x-ray imager was completed.

  Background: Significant improvement in the spatial resolution of x-ray imaging will result in much more accurate measurements of materials properties such as EOS. We have developed a new concept for significantly improving the spatial resolution. This concept may also be applicable to other problems in inertial fusion research such as improved diagnostics of implosions.

- In collaboration with Oxford University, we completed the first phase of the development of theoretical modeling of diffraction experiments to study perturbed shock wave propagation in condensed matter.

V. Ignition Target Design

Improvements in ignition target design and robustness studies, as well as the need to assess the accuracy of our calculational models, are the main factors that guide our ignition experimental campaigns. For example, details of ignition design calculations help define plasma conditions chosen for laser plasma instability experiments, requirements for time-dependent drive-symmetry diagnostics, and important processes to be investigated in hydrodynamic instability experiments. Los Alamos has taken the lead in developing ignition target designs based on beryllium ablator capsules. The Los Alamos effort in beryllium work draws substantially on weapons experience in both target design and fabrication and represents another important synergism between ICF and core weapons.

Additionally, work has continued on double shell targets that offer the advantage of not needing a cryogenic layer.

· Developed a viable hohlraum and drive for NIF double shell ignition targets. This non-cryogenic NIF ignition capsule uses a beryllium ablator, which collides with an internal gold shell.

VI. Radiation-Hydrodynamics Code Development

Crucial to the ICF program is development of computational tools to understand complex ICF target behavior. Development of computational tools in ICF often has direct relevance to improving the predictive capability for the stockpile. Large radiation hydrodynamics codes are used as the principal design tools for ICF experiments. While LASNEX, is and will remain, the workhorse 2-D radiation hydrodynamics code for the Los Alamos ICF program, we are beginning to explore development of 3-D predictive capabilities for ICF target analysis to address important issues such as hydrodynamic stability and the design of spherical hohlraums with tetrahedral illumination.

<u>Accomplishments</u>:

· Laser ray optics and laser energy deposition have been implemented in RAGE (3-D adaptive-mesh-refinement (AMR) code being developed under the ASCI program) and the capability has been tested in static geometries. This capability will eventually allow RAGE to model hohlraums in 3-D.

· We began moving LASNEX to the ASCI Blue SGI machines and have begun to test a number of physics and input/output subroutines on the new platform.

· The suite of non-LTE atomic data codes (CATS, GIPPER, etc.) has been optimized to the point of requiring an order of magnitude less run time and memory. These codes are being used to create detailed configuration (DCA) non-LTE models for gold which can be used by TDG, a LASNEX post-processor, to obtain detailed spectral information. The simplest possible DCA model (single-electron jumps only) has been processed by TDG and compared with experimental spectra obtained from gold spheres shot at Rochester in the mid 1980's. The comparison with experiment indicates that the qualitative properties of this simple DCA model are correct, but more complexity is needed to obtain quantitative agreement. The production of more complex models is in progress.

  Background: Presently, the average atom approach is the main computational approach for including non-LTE physics in ICF radiation-hydrodynamic simulations. The simplicity of this method makes it ideal for use as an in-line package when calculating in non-LTE mode. However, the accuracy of the average atom approach is suspect when compared with the experimental results described above. The ultimate goal of this project is to deliver computational alternatives to the average atom approach that would have applications to both ICF and stockpile issues.

VII. Diagnostic Development

Diagnostic development is key to the success of ICF and to the successful use of the National Ignition Facility (NIF) for both the pursuit of ignition and weapons physics understanding. Characterizing and tuning hohlraums and capsule behavior underpins all ICF experiments and will be particularly challenging on NIF. Target modeling accurately sets the bounds for ignition target performance but cannot predict the exact conditions (e.g. the precise laser pointing) required for a particular design. These conditions must be determined through precise and very accurately diagnosed experiments. Significant resources need to be invested in diagnostic development in order for ICF facilities to be fully utilized for both high precision ICF experiments and weapons physics experiments. Technologies associated with ICF diagnostic development are built upon many of the diagnostic techniques used in the underground nuclear testing program and thus this activity is highly synergistic with mainline weapon concerns. In addition, the development of diagnostics for NIF will insure that new technologies will be incorporated into established techniques, and will assure that new technologies will continue to be developed.

Accomplishments:

- Point projection radiography using 9-keV Zn backlighters to image the hydrodynamic evolution of thin wall hohlraums onto x-ray film at two separate times has been developed. This technique permits non-perturbative measurements of radiation case expansion and instability development in an integrated radiation-hydrodynamic experiment.

- We began the conceptual design of time resolved x-ray imaging system (TRXIS). The TRXIS diagnostic design has been refined with the review of an international diagnostic meeting held at the University of Rochester this past summer. The majority of engineering work has focused on the microchannel plate module which will allow researchers to capture 36 gated x-ray images with 4 ns total coverage. The engineering challenge is to design a imager with a large image format capability while maintaining sufficient microchannel plate gain.

- Design of an optical microscope for Omega was completed. A Burch microscope was designed which uses two concentric spherical mirrors and is diffraction-limited over a wide field of view. Light exits this TIM based diagnostic collimated so that magnifications can be changed outside vacuum with simple lens changes. The primary interest in this instrument is a streaked optical pyrometer for witness plate measurements of hohlraum drive.

- A preliminary design for a neutron bang-time detector for Omega was developed. This detector will allow neutron bang-times to be determined for yields and hard x-ray backgrounds typical of indirect drive experiments. The data acquisition and control system has been designed, and follows the front-end-processor model proposed for NIF.

- Major upgrades to gated monochromatic x-ray imager (GMXI) were completed. There have been several major upgrades to the GMXI diagnostic residing at the Omega laser. A new film pack which uses standard GXI type 35 mm film makes this diagnostic more user friendly and minimizes the chance for date loss. A larger vacuum box with improved precision rotary stages and better diagnostic pointing was also added this past year. This diagnostic which can image x-rays similar to a standard GXI, but with the ability to observe a single x-ray emission line has become a routinely used diagnostic at Omega.

- We recently enhanced our diagnostic testing capabilities by installing a small vacuum chamber in the front end room of Trident. We use extremely short (<1 ps) UV light of a few microjoules and focus light onto the face of a photocathode or microchannel plate. The configuration along with calibrated filters and detectors allows us to measure optical gate time, cathode linearity, MCP dynamic range, and cathode sensitivity. Trident continues to be an important facility for diagnostic development for Omega and the future National Ignition Facility.

- The 1D KB microscope which is currently under fabrication, has been designed for high spatial resolution ‘streaked’ x-radiography applications. In particular, Omega and Trident-upgrade EOS experiments. The novel optical design offers a theoretical resolution far superior to that of existing x-ray imagers. Rigorously modeling the remarkable tolerances to which the spherical mirrors have been fabricated and polished, predicts that the assembly and manufacturing errors of this optically contacted device will not detectably affect the performance. For the possible long term, we have a 2D 13.1 keV design for imaging NIF implosions at or near the point of peak compression.

VIII. Trident

Trident is Los Alamos National Laboratory's multipurpose laboratory for developing instrumentation and conducting experiments requiring high-energy laser-light pulses. As a user facility, it is operated primarily for Inertial Confinement Fusion (ICF) research, weapons physics, and basic research. Featured are flexible driver characteristics and illumination geometries, broad resident diagnostic capability, and flexible scheduling. The Trident facility includes a frequency-doubled Nd: glass laser driver, a high-vacuum target chamber, a basic optical and x-ray diagnostics suite, and ancillary equipment and facilities. A dedicated staff maintains and operates the facility and assists visiting experimenters.

Trident has played a role in diagnostic development in the National ICF program and in resolving fundamental plasma instability physics and studies of foam buffered direct drive. The Trident facility will continue to perform 800-1000 high energy target shots/year in support of Nova and Omega experimental campaigns as well as weapons physics, ICF and university user experimentation.

Accomplishments

- Conducted over 800 target shots.

- In collaboration with University groups from Imperial College, University of Nevada, University of Michigan, Oxford University, University of Rochester, and other institutions performed crucial experiments in many areas relevant to ICF physics. This kind of interaction has not only provided very valuable information for the ICF program but is a paradigm for the involvement of the academic community in the program and valuable precursor to the broader program of University physics envisioned by DOE for FY98.

IX. Optical Fabrication & Laser Science

Optical fabrication costs threaten the successful completion of the NIF. In collaboration with LLNL, the Los Alamos ICF program supports small focused technology development projects in laser science. The proposed increase in the NIF shot rate and the desire for higher peak powers and improved beam quality to better support NIF weapons physics users motivate this avenue of technology development.

Accomplishments

Optical Fabrication

- Rapid Pad polishing is an efficient technique for polishing out a ground optical surface and reaching a better than one wave figure, ready for completion with less than an hour on a planetary polisher. Initial work has shown success on 350 mm square parts; and most recently the technology has been scaled to NIF like dimensions of 1.4 meter in diameter. Unlike pitch, pad polishing retains its surface figure, producing a uniform result when used on a production basis. Coupled with the speed of production and low capital cost of overarm machines, it produces a very cost-effective approach, which will save the NIF project millions of dollars.

Laser Science

- Calculations in collaboration with LLNL personnel for efficient third harmonic generation of broad bandwidth and high dynamic range pulses using multicrystal designs have been completed. [D. Eimerl, *et. al., Opt. Lett.,* **22**, 1208 (1997)].

- The measurement of nonlinear indices has been extended this year to the measurement of cross phase modulation in fused silica, KDP and KD*P by the frequency-resolved optical gating technique. [G. Rodriguez, *et. al.*, CLEO, (1997)]

- Completed characterization of damage threshold for optical materials at grazing incidence that might be useful for pinholes for the NIF and for a Trident upgrade. We have shown that absorbing filter glass can survive approximately 100 times the normal incidence fluence (on the order of 5 kJ/cm^2 measured normal to the beam) at a two degree grazing angle. This concept will be further explored for pinhole design.

- Completed studies of damage thresholds for two spatially coincident pulses as a function of temporal separation. Data from these experiments has been supplied to Livermore to help to test their models of damage thresholds as a function of pulse shape.

X. Ignition Target Fabrication Technology

ICF target fabrication is vital for attaining ignition on NIF. This field has long been a fertile mix of complex materials science and characterization development. Although the National ICF program has made excellent progress in advancing the state of target fabrication we are far from being able to produce and characterize actual NIF targets. We will continue our efforts in the materials science of beryllium and its alloys, and in the properties of solid DT as they apply to fabrication of ignition capsules. Both the capability to fabricate beryllium shells and to perform the high pressure fills required of NIF ignition capsules overlap with capabilities required for the nuclear weapons mission at Los Alamos. Fabrication exploits the synergism of core weapons research and ICF because many of the scientists working on these complex problems are also working on the analogous weapons problems involving the same materials, such as fire resistance and neutron generation. In addition, the fabrication of targets for ongoing experiments at the three laser driver facilities in the program, Nova, Omega, and Trident, require advanced materials science efforts in, for example, foam fabrication and precision machining.

Accomplishments:

- Cryogenic D-T beta-layering on a toroidal insert made from pure beryllium shows that the RMS surface roughness of the solid D-T layer is approximately 1 µm, i.e., no worse than that measured on copper surfaces.

- To better measure D-T layer smoothness inside capsules, we began collaboration with UR/LLE to implement and develop their interferometric technique that can measure the influence of the supporting structures on beta-layering symmetry, as well as to analyze surface roughness in true spherical geometries.

- An iso-compositional braze of beryllium/6 percent Cu alloy has been tensile tested to the tensile strength of the alloy itself; a result that portends well for the fabrication of ignition capsules.

- The first test of a new lapping fixture was performed on 2 mm Be spheres made by adhesively bonding hemispheres.

- We continued developing resonant ultrasound (RUS) as a probe of cryogenic fuel symmetry within opaque capsules.

  Background: Resonant Ultrasound Spectroscopy (RUS) is the only experimental technique under development for the observation of cryogenic fuel symmetry inside opaque targets. Low-mode fuel layer distortions are extractable from degenerate-mode frequency splitting in the acoustic resonance spectrum of the target cavity. With sufficient sensitivity, real-time spectrum analysis could be used to observe the beta-layering process as well as the long-time surface symmetry. Preliminary studies have yielded sub-micron low-mode amplitude resolution in gas-filled room-temperature beryllium shells. A variety of RUS techniques are under investigation for improved sensitivity including the use of novel piezo-materials and optically-detected resonance analysis.

- A large portion of the Los Alamos target fabrication effort is to provide the necessary targets for ICF and weapons physics experiments at a variety of laser facilities; e.g., Trident, Nova, Omega. During FY97, the shear numbers total approximately 150 complex (hohlraum) targets and 1000 simpler targets. Laser schedules typically demand that development time ≤ fabrication time for the vast majority of these targets. However, most targets require development, and are not mere repeats of previous targets. A few of the more notable FY97 developments in this category were:

  1. Use of the fast-tool servo to cut azimuthal perturbations in cylindrical implosion targets. Though requested targets have had simple sinusoidal perturbations, this tool allows arbitrary perturbations to be cut with sub-micron precision on otherwise cylindrical or spherical surfaces.
  2. By backfilling low-density (30 mg/cc) foams with a low melting point solid surfactant, these foams can be machined with surface finishes representative of the cell size (2-3 microns). The surfactant is removed by a selective solvent, after which the resulting foam maintains its shape and uniform low density.
  3. The first implosion targets using tetrahedral hohlraums were fabricated in FY97. The thin-walled hohlraums were made in three different configurations, but all were assembled from two hemispherical halves.

- Glass shells have been filled with DT for both Nova and Omega.

- The design has been completed and construction started on an apparatus to synthesize tritium-exchanged deuterated GDP plastic to provide surrogate cryogenic targets for shots on Omega in FY98.

- We have initiated the design of a cryostat to enable tritium-testing of the GA permeation pressure cell which will allow the development of cool-down schedules for D-T filled spheres and will be used to observe beta-layering in filled cold targets.

- The designs for the glove boxes to contain the Fill/Transfer Station Cryostat have been completed. Specifications have been written, and a contract for construction of the gloveboxes have been placed.

- Los Alamos identified the need for a tritium cleanup system to support the OCTS. Requirements have been written and a conceptual design have been completed.

XI. Other ICF Activities:

The ICF program sponsors a number of external collaborations. These have helped grow capabilities within the Los Alamos ICF program and have been important addressing program deliverables.

Accomplishments:

- We have collaborated with the University of Wisconsin to produce a view-factor (or configuration-factor) radiation-transport code for modeling radiation drive symmetry in hohlraums.

- We collaborated with Professor Justin Wark, Oxford University, on developing the transient x-ray diffraction technique.

- In a collaborative experiment with VNIIEF (Sarov), we utilized the soft-x-ray spectrometer fabricated by them to measure radiation temperatures from “labyrinth” hohlraums on Trident. Temperatures in excess of 100 eV were obtained.